

**14259**  
**Soil**  
**2576.8 grams**

*CDR Get one (bag) for the fines and we'll start – I'd just say, just grab an undisturbed site out of each quadrant, we didn't hit with our feet. Cut it down to about a centimeter level – and fill the bag that way.*

*LMP Okay. You want the medium-size scoop or the big scoop for this?*

*CDR No actually – the trenching tool, now the medium size scoop is the best. All you've got to do is cut the surface to a depth of about a centimeter in an undisturbed area here – where we haven't picked up the rocks. Okay?*

*LPM Okay, I'll start over here in this undisturbed area.*

*CDR Yes, just get that area and then right here in this area. And fill up the bag to the line. Now I'll head on back to a little farther, get a fooball-size rock.*



Figure 2: Smooth area between LM and ALSEP where comprehensive sample was taken. NASA AS14-67-9388. Very few rocks.

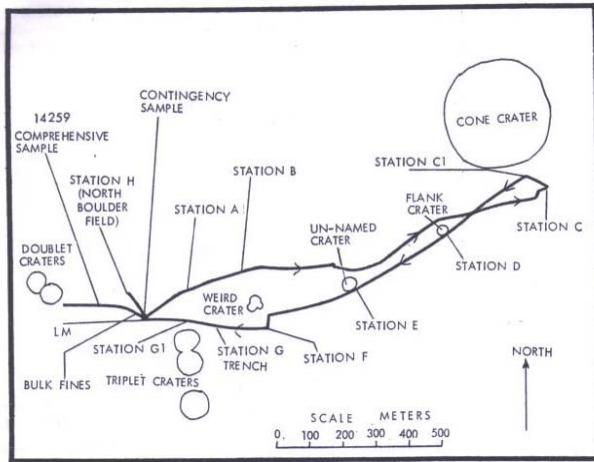


Figure 1: Sketch map of Apollo 14 sampling sites showing position of 14259 between LM and ALSEP.

## Introduction

A large soil sample was collected about 100 meters west of the LM after first picking up a suite of small rock samples (14264 to 14288) with the thongs (figure 2). This suite of samples, called a “comprehensive sample”, is comparable to rake samples and their soils collected on later missions.

As the transcript indicates, soil sample 14259 was collected from the top 1 cm in an undisturbed area.

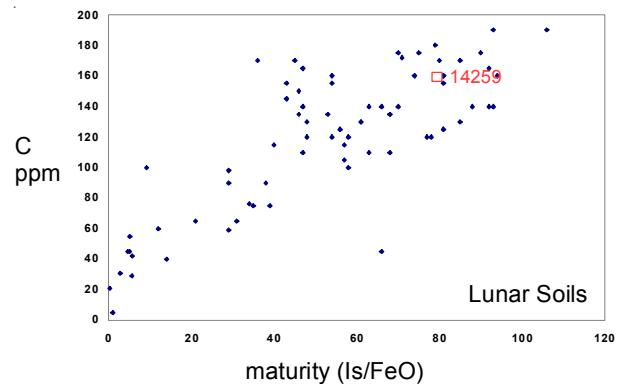


Figure 3: Carbon content and maturity index for 14259 compared with other lunar soil samples (data from Morris 1978 and Moore et al. 1972).

It was found to be mature and to have relatively high “activity” due to cosmic ray bombardment.

## Petrography

Morris (1978) reported the maturity index  $Is/FeO = 85$  (mature). The high agglutinate count (McKay et al. 1972; von Engelhardt et al. 1972) and high carbon

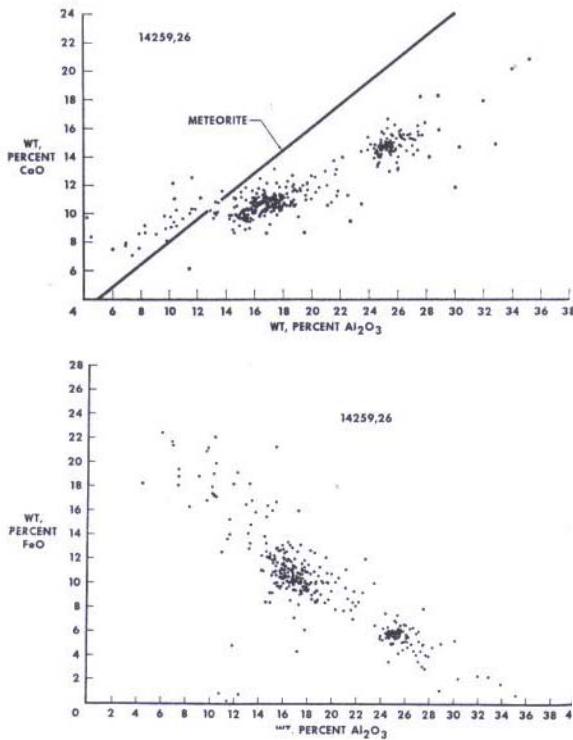


Figure 4: Chemical composition of glass particles in soil 14259 (Apollo Soil Survey). Note the 2nd cluster at ~ 26%  $\text{Al}_2\text{O}_3$ .

content (Moore et al. 1972) also indicate that this is a very mature soil.

King et al. (1972) reported the grain size distribution (figure 5) and Finkelman (1973) studied the finest fraction.

Phinney et al. (1975) and Carlson and Walton (1978) cataloged the small rock fragments from the area of the soil sample (table 3).

### Modal content of soils 14259

90 – 150 microns

From McKay et al. 1972

Agglutinates	51.7%
Basalt	1
Breccia	25.3
Anorthosite	
Norite	
Gabbro	
Plagioclase	4.7
Pyroxene	4.3
Olivine	
Ilmenite	
Glass other	12.8

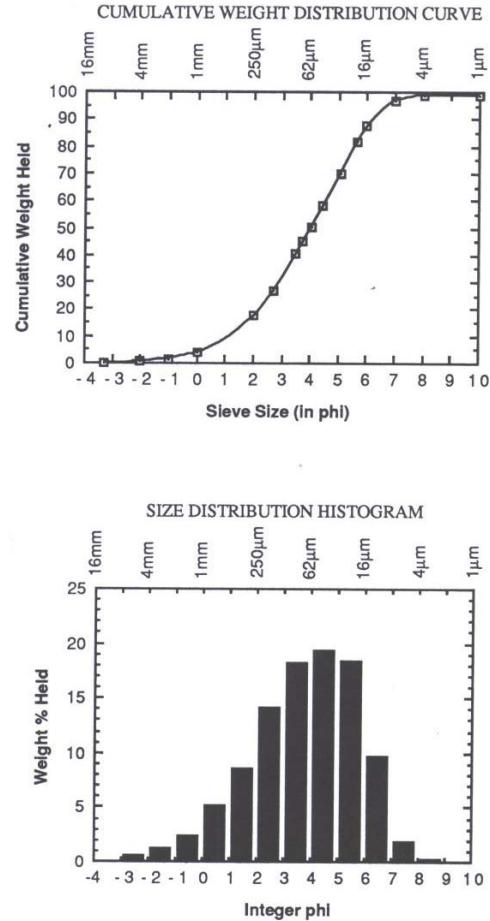


Figure 5: Grain size distribution for 14259 (Graf 1993, from data by McKay et al. 1972).

The Apollo Soil Survey (JSC) found groupings or clusters in the plots of glass compositions (figure 3, table 2). One of these groupings ( $\text{Al}_2\text{O}_3 = \sim 26$  wt. %) was also found to be present in other lunar soils (Reid et al. 1972) and may represent an average of the lunar highlands.

### Mineral mode for 14259

From Apollo Soil Survey

Glass	47.7
Feldspar	24.6
Plag.	23
K-spar	1.1
Mask.	0.5
Pyroxene	21.5
Opx.	8.7
Cpx.	4.6
Augite	8.2
Olivine	3.8
Oxides	1.7
Metal	0.7
Sulfide	0

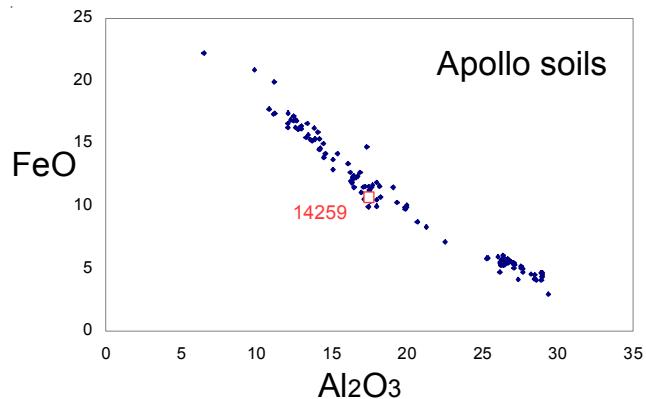


Figure 6: Composition of Apollo soil samples with 14259.

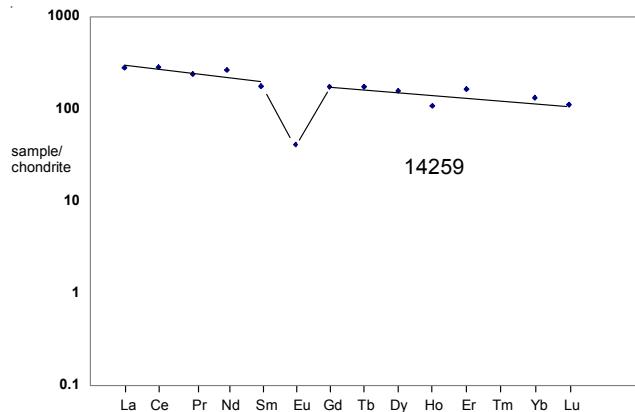


Figure 7: Normalized rare-earth-element diagram for 14259 (data from Wanke et al. 1972).

## Chemistry

LSPET (1971), Rose et al. (1972), Lindstrom et al. (1972), Wanke et al. (1972), Strasheim et al. (1972), Morgane et al. (1972), Baedecker et al. (1972), Willis et al. (1972) and Keith et al. (1972) all made measurements of the chemical composition of 14259 (table 1). Moore et al. (1972) reported 160 ppm carbon (figure 3).

## Cosmogenic isotopes and exposure ages

Keith et al. (1972) determined the cosmic-ray-induced activity of  $^{22}\text{Na}$  = 91 dpm/kg.,  $^{26}\text{Al}$  = 222 dpm/kg.,  $^{46}\text{Sc}$  = 0.7 dpm/kg.,  $^{54}\text{Mn}$  = 60 dpm/kg and  $^{56}\text{Co}$  = 60 dpm/kg. for 14259. Begemann et al. (1972) obtained  $^{26}\text{Al}$  = 212 dpm/kg. and  $^{36}\text{Cl}$  = 16.5 dpm/kg. Wahnen et al. (1972) measured  $^{22}\text{Na}$  = 89 dpm/kg.,  $^{26}\text{Al}$  = 170 dpm/kg. and  $^{53}\text{Mn}$  = 44 dpm/kg.

## Other Studies

Tatsumoto et al. (1972) studied the U, Th and Pb systematics and Heymann et al. (1972) reported rare gas data.

## Processing

Small rock samples sieved from this soil are tabulated along with the rocks picked up by thongs (table 3).

**Table 1. Chemical composition of 14259.**

reference weight	LSPET 71	Rose 72	Lindstrom72	Wanke72	Strasheim72	Morgan72	Baedecker72	Keith72	Willis72
SiO <sub>2</sub> %	48	48.16	(b)		47.5	(f)	48.15	(c )	
TiO <sub>2</sub>	1.8	1.73	(b)		1.42	(f)	1.82	(c )	
Al <sub>2</sub> O <sub>3</sub>	18	17.6	(b)		17.4	(f)	16.99	(c )	
FeO	10	10.41	(b)	10.3	(a)	10.3	(f)	10.58	(c )
MnO	0.18	0.14	(b)		0.13	(f)	0.136	(c )	
MgO	9.2	9.26	(b)		9.28	(f)	9.32	(c )	
CaO	11	11.25	(b)		10.8	(f)	10.71	(c )	
Na <sub>2</sub> O	0.52	0.61	(b)	0.68	(a)	0.63	(f)	0.65	(c )
K <sub>2</sub> O	0.5	0.51	(b)		0.48	(f)	0.47	(c )	
P <sub>2</sub> O <sub>5</sub>							0.46	(c )	
S %							0.46	(f)	
<i>sum</i>							0.101	(f)	
Sc ppm	21	(g) 28	(b) 21.9	(a) 23		(a, d)			
V	50	(g) 62	(b)			34	(c )		
Cr	1400	(g) 1780	(b) 1290	(a) 1310		(a, d)			1370 (f)
Co	39	(g) 38	(b) 37.5	(a) 36		(a, d) 33	(c )		
Ni	320	(g) 440	(b)		380	(a, d) 330	(c )	414	(d)
Cu	14	(g) 19	(b)		12.3	(a, d) 16	(c )		
Zn		24	(b)		22	(a, d) 53	(c ) 22	(d) 27	(d)
Ga		4.4	(b)		7.6	(a, d)		6.7	(d)
Ge ppb					590	(a, d)		750	(d)
As					0.076	(a, d)			
Se									
Rb	10	(g) 12	(b)		19	(a, d) 14	(c ) 15.4	(d)	
Sr	170	(g) 150	(b)			248	(c )		173 (f)
Y	170	(g) 285	(b)			210	(c )		200 (f)
Zr	720	(g) 800	(b) 590	(a)		720	(c )		961 (f)
Nb	40	(g) 67	(b)			54	(c )		61.3 (f)
Mo									
Ru									
Rh									
Pd ppb				20	(a, d)				
Ag ppb						26.5	(d)		
Cd ppb						83	(d) 93	(d)	
In ppb				34	(a, d)	34	(d) 37	(d)	
Sn ppb									
Sb ppb									
Te ppb						50	(d)		
Cs ppm			0.75	(a) 0.67	(a, d)	0.62	(d)		
Ba	570	(g) 1100	(b) 740	(a)		974	(c )		855 (f)
La	46	(g) 77	(b) 57.8	(a) 66		(a, d)			
Ce			178	(a) 170		(a, d)			
Pr				21		(a, d)			
Nd				120		(a, d)			
Sm		26.5	(a) 26			(a, d)			
Eu		2.63	(a) 2.29			(a, d)			
Gd			34			(a, d)			
Tb		5.9	(a) 6.3			(a, d)			
Dy			38			(a, d)			
Ho			6			(a, d)			
Er			26						
Tm									
Yb	24	(g) 30	(b) 21.4	(a) 21.5		(a, d)			
Lu			3.05	(a) 2.7		(a, d)			
Hf		22.5	(a) 21			(a, d)			
Ta		3.9	(a) 2.8			(a, d)			
W ppb				1700	(a, d)				
Re ppb						1.3	(d)		
Os ppb									
Ir ppb				16	(a, d)				
Pt ppb						18.6	(d) 12.5	(d)	
Au ppb				5.5	(a, d)				
Th ppm		14	(a) 14.3			6.6	(d) 10.7		
U ppm		3	(a) 3.79					14.4 (e)	
								3.5 (e)	

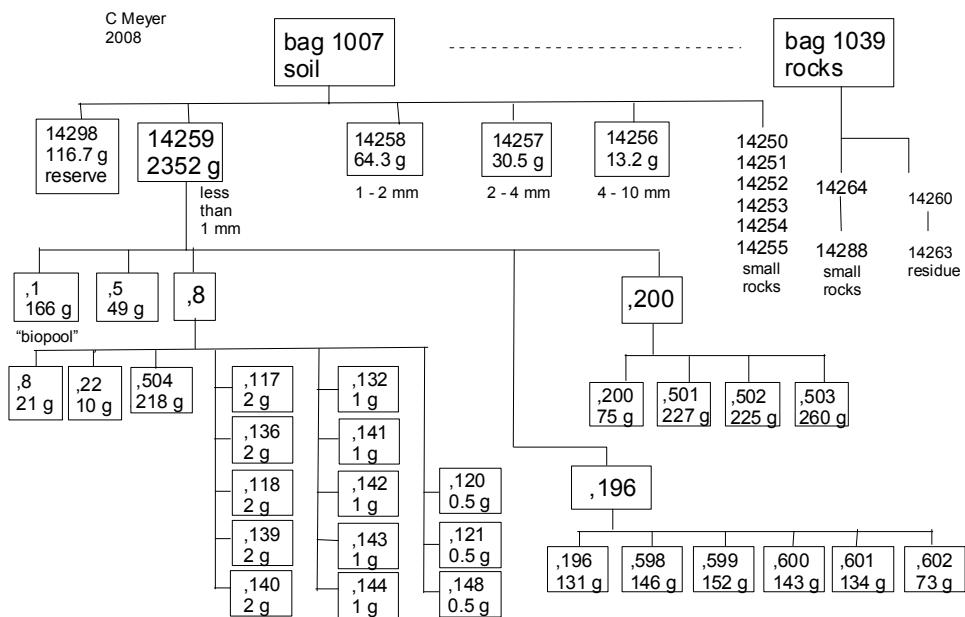
technique: (a) INAA, (b) microchemical, (c) various, (d) RANAA, (e) radiation counting, (f) XRF, (g) emission spec.

**Table 2: Average composition of glass types in 14259.**

from Apollo Soil Survey

name	Mare	FraMauro	Anor.Gab.	Gab.Anor.	granite	low-Si
proportion	11%	58%	28%	1%	1.50%	0.50%
SiO <sub>2</sub>	45.5	48	45.2	47.4	71.5	38
TiO <sub>2</sub>	2.8	2	0.36	0.14	0.4	0.2
Al <sub>2</sub> O <sub>3</sub>	10.9	17.1	25.6	31.3	14	34.5
FeO	18.1	10.6	5.6	3	1.8	1.2
MgO	11.2	8.7	7.8	2.2	0.7	5.6
CaO	9.6	10.8	14.8	14.8	2	20
Na <sub>2</sub> O	0.4	0.7	0.25	1	1	
K <sub>2</sub> O	0.32	0.6	0.1	0.2	6.5	

comprehensive sample



**Table 3: Small rocks from 14259 area.**

	wt. grams	name
14250	4.06	regolith breccia
14251	1.51	regolith breccia
14252	0.86	regolith breccia
14253	1.01	crystalline matrix bx.
14254	1.23	glass
14255	22.15	glass coated soil bx.
14264	118	vitric matrix breccia
14265	66	glass coated soil bx.
14266	7	fragmental breccia
14267	55	glass matrix breccia
14268	23	glass matrix breccia
14269	17	glass matrix breccia
14270	25.5	crystalline matrix bx.
14271	97.4	glass matrix breccia
14272	46.6	glass matrix breccia
14273	22.4	glass matrix breccia
14274	15.2	crystalline matrix bx.
14275	12.5	glass matrix breccia
14276	12.75	KREEP basalt
14277	7.6	glass matrix breccia
14278	7.6	breccia
14279	5.7	breccia
14280	6.2	glass matrix breccia
14281	12	glass matrix breccia
14282	1.9	glass matrix breccia
14283	1.25	crystalline matrix bx.
14284	1.5	breccia
14285	2.2	breccia
14286	4.4	breccia
14287	1.1	breccia
14288	3.4	glass matrix breccia
14260	~ 300	soil from rock bag

**References for 14259**

- Alexander E.C., Coscio M.R., Dragon J.C., Pepin R.O. and Saito K. (1980) K/Ar dating of lunar soils IV: Orange glass from 74220 and agglutinates from 14259 and 14163. Proc. 11<sup>th</sup> Lunar Planet. Sci. Conf. 1663-1677.
- Apollo Soil Survey (1971) Apollo 14 – Nature and origin of rock types in soil from Fra Mauro Formation. Earth Planet. Sci. Lett. 12, 49
- Apollo Soil Survey (1974) Phase chemistry of Apollo Soil Sample 14259. Modern Geology 5, 1-13.
- Baedecker P.A., Chou C-L. and Wasson J.T. (1972) The extralunar component in lunar soils and breccias. Proc. 3<sup>rd</sup> Lunar Sci. Conf. 1343-1359.
- Berdot J.L., Chetrit G.C., Lorin J.C., Pellas P. and Poupeau G. (1972) Track studies of Apollo 14 rocks and Apollo 14, Apollo 15 and Luna 16 soils. Proc. 3<sup>rd</sup> Lunar Sci. Conf. 2867-2881.
- Begemann F., Born W., Palme H., Vilcsek E. and Wanke H. (1972) Cosmic-ray produced radionuclides in Apollo 12 and Apollo 14 samples. Proc. 3<sup>rd</sup> Lunar Sci. Conf. 1693-1702.
- Cadogen P.H., Eglington G., Firth J.N.M., Maxwell J.R., May B.J. and Pillinger C.T. (1972) Survey of lunar carbon compounds: II. The carbon chemistry of Apollo 11, 12, 14 and 15 samples. Proc. 3<sup>rd</sup> Lunar Sci. Conf. 2069-2091.
- Finkelman R.B. (1973) Analysis of the ultrafine fraction of the Apollo 14 regolith. Proc. 4<sup>th</sup> Lunar Sci. Conf. 179-189.
- Graf J.C. (1993) Lunar Soils Grain Size Catalog. NASA Pub. 1265
- Keith J.E., Clark R.S. and Richardson K.A. (1972) Gamma-ray measurements of Apollo 12, 14 and 15 lunar samples. Proc. 3<sup>rd</sup> Lunar Sci. Conf. 1671-1680.
- King E.A., Butler J.C. and Carman M.F. (1972) Chondrules in Apollo 14 samples and size analyses of Apollo 14 and 15 fines. Proc. 3<sup>rd</sup> Lunar Sci. Conf. 673-686.
- Kramer F.E. and Twedell D.B. (1977) Apollo 14 coarse fines (4-10 mm) sample location and classification. JSC 12922
- Lindstrom M.M., Duncan A.R., Fruchter J.S., McKay S.M., Stoeser J.W., Goles G.G. and Lindstrom D.J. (1972) Compositional characteristics of some Apollo 14 clastic materials. Proc. 3<sup>rd</sup> Lunar Sci. Conf. 1201-1214.

- LSPET (1971) Preliminary examination of lunar samples from Apollo 14. *Science* 173, 681-693.
- McKay D.S., Heiken G.H., Taylor R.M., Clanton U.S., Morrison D.A. and Ladle G.H. (1972) Apollo 14 soils: Size distribution and particle types. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 983-995.
- Moore C.B., Lewis C.F., Cripe J., Delles F.M., Kelly W.R. and Gibson E.K. (1972) Total carbon, nitrogen and sulfur in Apollo 14 lunar samples. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 2051-2058.
- Morgan J.W., Laul J.C., Krahenbuhl U., Ganapathy R. and Anders E. (1972b) Major impacts on the moon: Characterization from trace elements in Apollo 12 and 14 samples. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 1377-1395.
- Morris R.V. (1976) Surface exposure indices of lunar soils: A comparative FMR study. *Proc. 7<sup>th</sup> Lunar Sci. Conf.* 315-335.
- Morris R.V. (1978) The surface exposure (maturity) of lunar soils: Some concepts and Is/FeO compilation. *Proc. 9<sup>th</sup> Lunar Sci. Conf.* 2287-2297.
- Phinney W.C., Simonds C.H. and Warner J. (1975) Description, Classification and Inventory of the comprehensive sample from Apollo 14. Curator's Catalog, pp. 46.
- Reid A.M., Ridley W.I., Harmon R.S., Warner J., Brett R., Jakes P. and Brown R.W. (1972a) Highly aluminous glasses in lunar soils and nature of lunar highlands. *Geochim. Cosmochim Acta* 36, 903.
- Reid A.M., Warner J., Ridley W.I., Johnston D.A., Harman R.S., Jakes P. and Brown R.W. (1972b) The major element compositions of lunar rocks inferred from glass compositions in lunar soils. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 363-379.
- Reid A.M., Ridley W.I., Jakes P. and Warner J.L. (1971) Microprobe analyses of glasses from Apollo 14 sample 14156. NASA TMX 58081 JSC, Houston.
- Rose H.J., Cuttitta F., Annell C.S., Carron M.K., Christian R.P., Dwornik E.J., Greenland L.P. and Ligon D.T. (1972) Compositional data for twenty-one Fra Mauro lunar materials. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 1215-1229.
- Stasheim A., Jackson P.F.S., Coetzee J.H.J., Strelow F.W.E., Wybenga F.T., Gricius A.J., Kokot M.L. and Scott R.H. (1972a) Analysis of lunar samples 14163, 14259 and 14321 with isotopic data for  $^{7}\text{Li}/^{6}\text{Li}$ . *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 1337-1342.
- Sutton R.L., Hait M.H. and Swann G.A. (1972) Geology of the Apollo 14 landing site. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 27-38.
- Swann G.A., Bailey N.G., Batson R.M., Eggleton R.E., Hait M.H., Holt H.E., Larson K.B., McEwen M.C., Mitchell E.D., Schaber G.G., Schafer J.P., Shepard A.B., Sutton R.L., Trask N.J., Ulrich G.E., Wilshire H.G. and Wolf E.W. (1971) Preliminary geologic investigations of the Apollo 14 landing site. In *Apollo 14; Preliminary Science Report*. NASA SP-272, 39-85.
- Swann G.A., Bailey N.G., Batson R.M., Eggleton R.E., Hait M.H., Holt H.E., Larson K.B., Reed V.S., Schaber G.G., Sutton R.L., Trask N.J., Ulrich G.E. and Wilshire H.G. (1977) Geology of the Apollo 14 landing site in the Fra Mauro highlands. *U.S. Geological Survey Professional Paper* 880.
- Tatsumoto M., Hedge C.E., Doe B.R. and Unruh D.M. (1972a) U-Th-Pb and Rb-Sr measurements on some Apollo 14 lunar samples. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 1531-1555.
- Taylor S.R., Kaye M., Muir P., Nance W., Rudowski R. and Ware N. (1972) Composition of the lunar uplands: Chemistry of Apollo 14 samples from Fra Mauro. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 1231-1249.
- von Engelhardt W., Arndt J., Stöffler D. and Schneider H. (1972) Apollo 14 regolith and fragmental rocks, their compositions and origins by impacts. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 753-770.
- Wahlen M., Honda M., Imamura M., Fruchter J.S., Finkel R.C., Kohl C.P., Arnold J.R. and Reedy R.C. (1972) Cosmogenic nuclides in football-sized rocks. *Proc. 3<sup>rd</sup> Lunar Sci. Conf.* 1719-1732.
- Wasson J.T., Chou C-L., Bild R.W. and Baedecker P.A. (1973) Extralunar materials in Cone-crater soil 14141. *Geochim. Cosmochim Acta* 37, 2349-2353.